APPENDIX 6-2

EVALUATION OF NNR AND PUMP STATIONS
TASK 5.3.3.6.2 - HYDRAULIC MODEL SUMMARY TECHNICAL MEMORANDUM

BLACK & VEATCH

TECHNICAL MEMORANDUM

South Florida Water Management DistrictB&V Project 141522
EAA Reservoir A-1 B&V File:
Work Order No. 5 First Issue: May 26, 2005
Last Updated:

Task 5.3.3.6.2 Hydraulic Model Summary Technical Memorandum
Evaluation of NNR and Pump Stations

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Task 5.3.3.6.2 Hydraulic Model Summary Technical Memorandum
Evaluation of NNR and Pump Stations

To: Distribution

From: Frank Means, Klint Reedy

1. OBJECTIVE

All HEC-RAS models and calculations are in NGVD29, both input and output results. To convert to NAVD88 subtract 1.4 ft from NGVD29, (NGVD29-1.4 ft=NAVD88). Conversion to NAVD88 has been completed for the text in the BODR. Calculations and model runs are in NGVD29 and text in the BODR is in NAVD88 unless otherwise stated.

The overall objective of the Hydraulic Modeling subtask is to evaluate the hydraulic characteristics of the regional conveyance system to define required modifications to existing facilities and design criteria for new facilities that will be used to transfer water into and out of the EAA Reservoir A-1. Specific objectives of this evaluation include:

1.1 Define Hydraulic Characteristics of the Existing NNR Canal

This task includes evaluating the existing North New River (NNR) canal to determine the following:

- Current capacity to transfer water from north to south into Reservoir A-1.
  - During wet periods when farmers are contributing lateral flows.
  - During dry periods when no lateral flows are present.
- Current capacity to transfer water from the south (Reservoir A-1) to the north for irrigation purposes.
- Water surface elevations at key locations to assist with new facility layout.

1.2 Identify Potential Canal Modification(s) / Improvement(s)

This task includes evaluating potential modifications to the existing NNR canal to identify the following:

- Potential increased capacity if existing high point (hump) is removed.
- Potential capacity if modifications allow maximum velocity to exceed 2.5 fps.

1.3 Estimate Operating Ranges of the New Project Facilities

The results from the above evaluations will be used to provide preliminary hydraulic information required to prepare conceptual configurations of the following:

- New supply canal between NNR canal and Reservoir A-1
- New pump station
- Gate and Spillway Structures for Reservoir A-1
- Potential modifications to existing facilities.

2. DESIGN CONDITIONS

This evaluation focuses on modeling a series of potential operating conditions as required to develop a range of estimated flows and approximate water levels at key location within the regional canal system. Specifically, this evaluation focuses on defining available flows and estimated water levels along the NNR canal between Lake Okeechobee and the G-370 pump station. Figure 1 provides an overview of the project area showing the proximity of Lake Okeechobee, the NNR canal, and the proposed Reservoir A-1.

Figure 2 provides a profile of the NNR canal from Lake Okeechobee to the G-370 pump station. In addition to the existing facilities, Figure 2 shows the anticipated location of the new Northeast pump station that will transfer water between the NNR canal and Reservoir A-1.

HEC-RAS calculates energy loss based on the geometry of the canal and roughness of the canal at each defined canal cross section. Manning’s “n” values are used to specify the canal roughness. The existing HEC-RAS model previously compiled as part of the *“Bolles & Cross Canals Preliminary-Hydraulics Report”* included Manning’s “n” values for each cross section. A. D. A. Engineering was also consulted on the roughness coefficients being used in the main canals. (Copp, 6/22/2005). A. D. A. Engineering is using 0.028 for a main channel Manning’s “n” value. Mike 11 is being used by A. D. A. Engineering for the hydrologic modeling. The Mike 11 calculations involving Manning’s “n” is slightly different than how HEC-RAS uses Manning’s “n”. Being conservative we chose to use a Manning’s “n” of 0.03 for the main channel. This is also consistent with the *“Bolles & Cross Canals Preliminary-Hydraulics Report”*. For a further discussion on the Manning’s “n” value chosen refer to Section 6 Hydraulics – Head Loss.

A wide variety of potential operating conditions were evaluated including dry weather operating conditions with Lake Okeechobee supplying 100 percent of the flows to the NNR canal, wet weather conditions with both Lake Okeechobee and runoff contributing to the flows in the canal, and dry weather conditions with Reservoir A-1 supplying flows to the north. The following sections describe the assumptions for each potential operating or design condition.

2.1 Design Condition 1: NNR Canal Flowing South with no Lateral Flows

During dry weather conditions the water supply for the NNR canal is anticipated to be either Lake Okeechobee or Reservoir A-1. Design Condition 1 evaluates a series of flows that can be conveyed in the NNR canal from Lake Okeechobee to the Northeast pump station and the G-370 pump station assuming a maximum velocity of 2.5 fps, a minimum two foot freeboard is maintained, and a maximum water level of 11.6 ft (NAVD) at the Bolles/Cross canal intersection is observed.

Figure 3 provides a schematic of the simulated dry weather flow conditions with the NNR flowing south. Table 1 summarizes the resulting flows and water surface elevations at key locations in the NNR canal. Section 5, Results, describes how these results assist in providing initial hydraulic criteria used to develop concepts for the Northeast pump station and Reservoir A-1 hydraulic structures.

2.2 Design Condition 2: NNR Canal Flowing South with Lateral Flows

During wet weather conditions the NNR canal is anticipated to flow south towards Reservoir A-1 and convey water from both Lake Okeechobee and lateral flows from runoff pumped from the local farm lands into the canal. Design Condition 2 evaluates a series of flows that can be conveyed south in the NNR canal assuming a maximum velocity of 2.5 fps, a minimum two foot freeboard, and a maximum water level of 11.6 ft (NAVD) at the Bolles/Cross canal intersection.

Table 2 summarizes the resulting flows and water surface elevations at key locations in the NNR canal assuming a ¾-inch runoff per day pumping rate is occurring from the farm lands along with flow being discharged from Lake Okeechobee. Table 3 summarizes the resulting flows and water surface elevations at key locations in the NNR canal assuming a 1 ½-inch runoff per day pumping rate is occurring from the farm lands along with flow being discharged from Lake Okeechobee. Figure 4 provides a schematic of the simulated flow conditions under wet conditions with the NNR flowing south. Section 5, Results, describes how these results help define the initial criteria used to develop preliminary design concepts for conveying water south.

2.3 Design Condition 3: NNR Canal Flowing North from Reservoir A-1

During dry weather conditions, water stored in Reservoir A-1 can be delivered north via the NNR canal to meet farming demands along the NNR canal or to supplement flows in the Bolles and Cross canals. Design Condition 3 evaluates a series of operating conditions that help define the anticipated flow rates and corresponding water levels when delivering water north from Reservoir A-1 assuming a maximum velocity of 2.5 fps and a minimum two foot freeboard is maintained. Table 4 summarizes the results of this evaluation. Section 5, Results, describes how these results help define the initial criteria used to develop preliminary design concepts for conveying water north.

2.4 Design Condition 4: Modified NNR Canal (Removal of Hump)

There is an existing high point or "hump" within the NNR canal between River Station (RS) 21 and 24, south of the Bolles/Cross canal intersection. This high point was removed in the model and flow conditions similar to Design Conditions 1 and 3 were simulated to determine the potential for capacity improvements. As with the previous design conditions, the velocity was limited to 2.5 fps and a minimum 2 foot freeboard was maintained.

Table 5 summarizes the resulting flows and water surface elevations at key locations in the NNR canal assuming the removal of the hump, water flowing south, and no lateral flows. Table 6 summarizes the resulting flows and water surface elevations at key locations in the NNR canal assuming the removal of the hump, water flowing north, and no lateral flows. Section 5, Results, reviews these findings and makes observations regarding the impact of potential NNR modifications to the conceptual design criteria.

2.5 Design Condition 5: NNR Canal Capacity without Velocity Limits

Design Conditions 1 through 4 evaluate the hydraulic characteristics of the NNR canal while limiting the velocity to no more than 2.5 fps and maintaining a minimum 2 foot freeboard. Design Condition 5 performs a brief evaluation of the NNR capacity to convey water south maintaining the desired 2 foot freeboard criteria, but allowing the velocity to exceed 2.5 fps. Table 7 Run #2 illustrates one of the upper limits of the capacity in the NNR canal when flowing south assuming a 2 foot freeboard is maintained and no velocity restrictions are in place, along with removing the hump and only operating G-370 at a capacity of 1850 cfs.

3. MODEL CONFIGURATION

The U.S. Army Corps of Engineers Hydrologic Engineering Center River Analysis System (HEC-RAS 3.1.3 May 2005) computer model was used to analyze the hydraulic characteristics of the NNR canal. An existing HEC-RAS model was previously compiled and was provided by the District on a CD-ROM included with the "*Bolles & Cross Canals Preliminary-Hydraulics Report.*" The specific HEC-RAS model that was used for the analysis described herein was, "*existing.prj*," which contained reaches for the Miami River, North New River, Bolles canal, and the Cross canal. A plan view of the provided model layout is illustrated Figure 5.

In order to focus on the ability of the NNR canal to convey water to and from Reservoir A-1, the model of the regional canals was dissected to only include the NNR canal. The model used for this analysis begins at Lake Okeechobee and extends south to structure S-7. The connections to the STA 3/4 Supply canal, Bolles and Cross canals were removed to be consistent with the portions of the system already presented on Figures 3 and 4.

Various model configurations were developed from the original model. The upstream end of the model is River Station 30 (RS 30). The Bolles and Cross canal intersection is located at approximately RS 24. The proposed Northeast pump station is located at approximately RS 16. G-370 pump station is located at RS 8. Models were constructed to determine the capacity in the NNR canal with flow traveling north to south, from Lake

Okeechobee to G-370 pump station. Models were also constructed with flow traveling south to north beginning at G-370 flowing to the Bolles and Cross connection.

3.1 Model Boundary Conditions

The open channel modeling was performed using the steady state option within HEC-RAS. The mixed flow regime mode was utilized in the modeling. To operate with a mixed flow regime, upstream and downstream boundary conditions are typically required to be defined within the model. However, due to the flat slope (i.e. lack of relief) of the NNR canal all flows are in the subcritical flow regime and therefore upstream boundary conditions for the modeling scenarios were not required. Although not required, the upstream boundary conditions were set at critical depths to allow HEC-RAS to operate in the mixed flow regime mode.

3.2 Assumed Inflow and Outflow Conditions

The steady flow model is used to simulate all the inflows and outflows to and from the NNR canal. Inflows are assumed to be flows conveyed downstream from Lake Okeechobee to the Bolles/Cross intersection or lateral inflows representing farm pump discharges into the NNR canal between the Bolles/Cross intersection and the G-370 pump station.

As shown on Figure 3, RS 16 is located just south of the future Northeast pump station. When in operation, the Northeast pump station will extract water from the NNR canal and transfer towards Reservoir A-1. Therefore, when simulating the Northeast pump station operation, the flow in the NNR canal is reduced by the simulated flow rate of the Northeast pump station and the resulting flow at RS 16 is the flow that bypasses the Northeast pump station and remains in the NNR canal.

At RS 15 and RS 11 there are more lateral inflow points. After RS 11, the total remaining flow in the NNR canal is conveyed downstream to the G-370 pump station, where it is assumed that all remaining flows are pump out of the NNR canal and into the A-1 Reservoir.

3.3 Modeling NNR Flowing North to South under Dry Conditions

For the dry weather condition all flows are assumed to come from Lake Okeechobee and be conveyed to the Bolles/Cross canal intersection via the regional canal system. For the configuration where the flow is conveyed north to south, the downstream boundary conditions are dependent upon the WSEL required to operate the G-370 pump station. For these modeling analyses the WSEL on the suction side of the G-370 pump station were set at 8.6 ft, 7.6 ft, and 6.6 ft NAVD.

3.4 Modeling NNR Flowing South to North under Dry Conditions

For the configuration where the flow is conveyed south to north, a downstream boundary condition was established at the Bolles and Cross connection. At this point the downstream boundary conditions were varied from 8.6 ft to 10.6 ft NAVD.

3.5 Modeling NNR Flowing North to South under Wet Conditions

During wet weather conditions, water will collect in the agricultural areas and the farmers must pump the rain water off the farm lands and into the adjacent canals. These wet weather lateral inflows are estimated from modeling results performed by A. D. A. Engineering, Inc utilizing a 2 x 2 simulation model of the entire EAA area. For this analysis, A.D.A provided estimated lateral inflow values assuming ¾ inches of runoff per day and 1-1/2 inches of runoff per day. Table 8 summarizes the estimated lateral inflow for each assumed runoff event and the location along the canal where the flow is anticipated to be introduced to the NNR canal.

3.6 Modeling the Northeast Pump Station Operating Range

Various scenarios were modeled to develop tables and curves for assisting in the design of the Northeast pump station. These scenarios included transferring water into Reservoir A-1 under a large range of wet weather conditions and dry weather conditions. These scenarios also considered how a large range of potential G-370 pump station operating conditions could impact the Northeast pump station.

The analysis evaluated utilizing the Northeast pump station to transfer flow out of Reservoir A-1. This condition is assumed to occur during the dry season when water stored in Reservoir A-1 is utilized to meet water demands. Because south to north flows are only assumed to occur during the dry season, no lateral inflows are assumed. Also the G-370 pump station is not operating under this scenario.

4. MODEL CALIBRATION, VERIFICATION AND RELIABILITY

Black & Veatch modified a previously compiled HEC-RAS model that was provided on the CD-ROM included with the "*Bolles & Cross Canals Preliminary-Hydraulics Report.*" In addition to making modifications to the existing model to incorporate and evaluate the proposed new facilities, Black & Veatch utilized other hydraulic modeling tools to confirm the HEC-RAS modeling was simulating realistic conditions. Specifically, spreadsheets and hand calculations were performed to double check the HEC-RAS results.

In addition to verifying that the model was calculating the expected water surface elevations, coordination with A. D. A. Engineering, Inc assisted with confirmation that the assumptions for lateral inflows during ¾" and 1.5" runoff events are consistent with runoff results utilized by other project teams.

5. RESULTS

This section focuses on interpreting the results of each of the modeling scenarios performed in Section 2, Design Conditions, and provides initial criteria used to develop the preliminary design concepts presented in related project technical memorandums.

5.1 Hydraulic Characteristics of NNR Canal (Existing Conditions)

Design Conditions 1, 2, and 3 and Tables 1, 2, 3, and 4 all evaluate the existing NNR canals ability to convey water to and from Reservoir A-1. The following summarizes the findings for these analyses.

5.1.1 NNR Canal Flowing South During Dry Season

During the dry season, the water level in the NNR canal between the Bolles/Cross intersection and the G-370 pump station is dependent on the operation of three facilities: 1) pumping rate and set water level at the G-370 pump station 2) pumping rate at the Northeast pump station 3) operation of the conveyance facilities upstream of the Bolles/Cross intersection (supply rate).

Varying the pumping rates, water levels, and available supply rates, a wide variety of operating conditions can be achieved. Table 1 depicts the resulting water levels in the NNR canal for three different operating conditions. The following summarizes the findings:

- Due to velocity restrictions, G-370 is limited to 2350 cfs.
- Reducing G-370 demands allows for greater Northeast pump station flows.
- Maximum flow from Bolles/Cross is achieved with two G-370 pumps on-line.

In summary, Table 1 indicates that when flowing the NNR canal south in dry seasons, Run #1 represents the maximum supply that can be delivered south to G-370, Run #2 represents the maximum flows that can be taken from Bolles/Cross, Run #3 represents the maximum flows that can be delivered to Reservoir A-1.

5.1.2 NNR Canal Flowing South During Wet Season

During the wet season, the water level in the NNR between the Bolles/Cross intersection and the G-370 pump station is dependent on the lateral flows pumped into the canal from the farmers and the operation of three facilities: 1) the G-370 pump station 2) the Northeast pump station 3) operation of the conveyance facilities upstream of the Bolles/Cross intersection.

Varying the pumping rates, water levels, and available supply rates a wide variety of operating conditions can be achieved. Tables 2 and 3 depict the resulting water levels in the NNR canal for six different wet season operating conditions. These tables identify the following:

- Due to velocity restrictions, G-370 is limited to 2350 cfs.
- Reducing G-370 demands allows greater Northeast pump station flows.
- Maximum flows are realized when the operation of the Northeast pump station and G-370 pump station are coordinated to limit total energy losses.

5.1.3 NNR Canal Flowing North During Dry Season

During the dry season, water stored in Reservoir A-1 could be discharged into the NNR canal and delivered north to farmers along the NNR canal or delivered to the Bolles and Cross canals. The water level in the NNR flowing north during the dry season is dependent on the operation of three facilities: 1) water level at the Bolles/Cross intersection 2) Reservoir A-1 gate structures 3) pumping rate of the Northeast pump station when pumping is required to flow north.

Varying the water level at the Bolles/Cross intersection and varying discharge rates for Reservoir A-1 will allow for a wide variety of operating conditions. Table 4 depicts the resulting water levels in the NNR canal for three operating conditions delivering water north from Reservoir A-1. This table identifies the following:

- Due to freeboard limitations and berm elevations, only limited flows are possible when the water level at Bolles/Cross is greater than 10 ft (NAVD).
- Due to high velocities at the hump, only limited flows are possible when the water level at Bolles/Cross is less than 8 ft (NAVD).
- Optimum setting for conveying flow north requires setting the WSEL at the Bolles/Cross canals between 8 and 9 ft (NAVD).

5.2 Hydraulic Characteristics of NNR Canal (Modified Conditions)

Design Conditions 4 and 5 and Tables 5, 6, and 7 all evaluate the existing NNR canals ability to convey water with improvements made to the existing canal or by operating the canal beyond the current velocity limit of 2.5 fps. The following summarizes the findings of these analyses.

5.2.1 NNR Canal Flowing South without Hump

Within the model the hump located between the Bolles/Cross canal intersection and the proposed Northeast pump station was removed. New simulations for conveying water south were evaluated utilizing the modified model and the results are summarized in Table 5. Comparing the results in Table 5 with Table 1, the impact of the hump on the hydraulic capacity of the NNR canal, conveying water south, can be identified. The following summarizes the findings:

- Removing the hump allows for up to a seven percent increase in the capacity to convey water south from the Bolles/Cross canal intersection.
- Greater than seven percent increase may be possible, but velocity restrictions limit the potential benefits.

5.2.2 NNR Canal Flowing North without Hump

New simulations for conveying water north were also evaluated utilizing the modified model described in section 5.2.1. The results are summarized in Table 6. Comparing the results in Table 6 with Table 4, the impact of the hump on the hydraulic capacity of the NNR canal conveying water north can be identified. The following summarizes the findings:

- Removing the hump allows for between seven percent and 11 percent increase in the capacity to convey water north from Reservoir A-1.
- With the hump removed, the canal section directly upstream of the Northeast pump station (RS 17) becomes the new bottle neck.

5.2.3 NNR Canal Flowing South without Velocity Restrictions

To obtain a better understanding of the hydraulic characteristics of the NNR canal, several simulations were performed omitting the velocity limit. Although the velocity was allowed to exceed 2.5 fps, the minimum freeboard and target water levels were still maintained. This evaluation resulted in the following findings:

- Only minor increases (about 4%) in capacity are realized if the system is operated to match the same target water levels.
- Significant increases in capacity (25%) can be realized if the downstream water levels are lowered, the existing hump is removed, lateral inflow is maximized, and the velocity is allowed to exceed 2.5 fps.

5.3 Estimated Operating Ranges of Project Facilities

The primary objective of the analysis summarized in Tables 1 through 7 is to provide hydraulic criteria for the conceptual design of project facilities. The following sections summarize the estimated operating ranges on key project facilities.

5.3.1 Estimate Operating Ranges of the Northeast Pump Station

Design Conditions 1, 2, 4, and 5 and Tables 1, 2, 3, 5, and 7 all evaluate the use of the new Northeast pump station to pump water into Reservoir A-1 under a wide variety of potential operating conditions. Additionally, Design Conditions 3 and Table 4 evaluate the use of the Northeast pump station to pump water out of Reservoir A-1. Figure 6 presents a scatter plot showing the estimated pumping heads for each of the evaluated operating conditions.

As shown on Figure 6, the pumping head varies between zero ft when the reservoir level and canal level are approximately the same to a little over 12 ft when the WSEL in the canal is less than 9 ft (NAVD) and the reservoir water level is equal to the high WSEL of 21 ft (NAVD). This range of potential operating conditions has been considered during the conceptual design of the Northeast pump station, which will be presented in the Basis of Design Memorandum to be issued in late July 2005.

5.3.2 Estimate Operating Ranges of the G-370 Pump Station

As shown on Tables 1 through 3 the WSEL at the G-370 pump station is typically set as the downstream control. In this evaluation, the suction side of G-370 was held constant at 8.6 ft (NAVD) and the flow rate varied between 925 cfs and 2350 cfs. This information will assist in defining any required modifications to the existing G-370 pump station.

5.3.3 Estimate Operating Ranges of the Connector Canal

The connector canal is the proposed canal that will connect the existing NNR canal to Reservoir A-1. In order to prepare a preliminary layout of this canal, the estimated total flow to and from Reservoir A-1 must be defined. Upon reviewing Figure 6, the flow could vary between 500 cfs and 3000 cfs. Conceptual layouts of the connector canal are presented in the *(June 2005 Draft) Canal Alternatives Technical Memorandum* prepared by Black & Veatch as part of Work Order No. 7.

5.3.4 Estimate Operating Ranges of Reservoir A-1 Gate Structures

Gate structures on Reservoir A-1 will be utilized to control the release rate of water from Reservoir A-1. Because water could be released into the NNR and flow both north and south the designed release rates for the gates may exceed the maximum capacity of the NNR flowing north. However, at a minimum, the gates should be capable of releasing between 1000 cfs and 3000 cfs. Operation of the gates is discussed in the BODR Section 20 – Operations and Maintenance.

6. SUMMARY AND CONCLUSIONS

The overall objective of the Hydraulic Modeling subtask was to evaluate the hydraulic characteristics of the regional conveyance system to define required modifications to existing facilities and design criteria for the new facilities that will be used to transfer water into and out of the EAA Reservoir A-1. Specific objectives of the evaluation include:

- Define Hydraulic Characteristics of the Existing NNR Canal
- Identify Potential Canal Modification(s) / Improvement(s)
- Estimate Operating Ranges of New Project Facilities

6.1 Hydraulic Characteristics of the NNR Canal

The hydraulic characteristics of the existing NNR canal were evaluated for a wide range of operating conditions and are summarized on Tables 1 through 7. Locations along the canal with potential velocity restrictions are shown on Figure 7. A. D. A. Engineering Inc. is evaluating on improvements to the northeast area of the EAA and believes that approximately 5,000 cfs could be conveyed to the Bolles and Cross confluence on the NNR canal (Copp, 7/12/2005). This flow amount and water surface elevations on the surrounding canals are currently being investigated by A. D. A. Engineering and will be confirmed at a later date. If 5,000 cfs is able to be conveyed to Bolles and Cross, then improvements to the capacity of the NNR between the Bolles and Cross confluence and the proposed Northeast Pump Station should be considered. In addition to the flows being confirmed by A. D. A. Engineering arriving at the Bolles and Cross confluence, Black & Veatch considered an additional 250 cfs being added to the NNR canal. This flow did show an increase in the percentage of time that the reservoir is full. Therefore, improvements to the capacity of the NNR canal between the Bolles and Cross confluence and the proposed Northeast Pump Station should be considered in a future work order.

6.2 Potential Canal Modifications / Improvements

Based on the preliminary evaluation summarized herein, removing the high point (hump) between the intersection of the Bolles/Cross canals and the proposed Northeast pump station would only provide minor increases in capacity because of other constraints that exist.

6.3 Operating Ranges of the New Project Facilities

The anticipated operating ranges for the Northeast pump station are presented in Tables 1 through 7 and summarized on Figure 6.

7. REFERENCES

Jacobs/MWH, *Bolles & Cross Canals Preliminary-Hydraulics Report.* June 15, 2004.

C. Brockway. *Canal Alternatives Technical Memorandum (Draft).* June 2005.

Copp, R. (A. D. A. Engineering), Personal Communication, June 22, 2005.

Copp, R. (A. D. A. Engineering), Personal Communication, July 12, 2005.

TABLES

Table 1 NNR Flowing South with no Lateral Flows
(All Elevations are in NAVD)

Run #	G-370 PS Flow (cfs)	G-370 PS WSEL (ft)	Northeast PS Flow (cfs)	Northeast PS WSEL (ft)	B/C Flow (cfs)	Bolles/ Cross WSEL (ft)	Lateral Flows (cfs)
1	2350 (VC)(1)	8.6 (S)	525 (S) (EC)	9.9 (C)	2875 (C) (EC)	11.6 (C) (EC)	0 (S)
2	1850 (S)(2)	8.6 (S)	1260 (S)(VC)	9.4 (C)	3110 (C) (VC)	11.5 (C)	0 (S)
3	925 (S)(3)	8.6 (S)	2025 (S)(VC)	8.8 (C)	2950 (C) (VC)	10.8 (C)	0 (S)

(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable
(EC) – Elevation controlled variable (FC) – Freeboard controlled variable.

(1) Existing pump capacity is 925 cfs each, 2,350 cfs flow rate requires throttling 3 pumps to 785 cfs each.
(2) Two 925 cfs pumps.
(3) One 925 cfs pump.

Run 1: Setting the WSEL at 8.6 ft (NAVD) resulted in a calculated maximum allowable flow rate of 2350 cfs at G-370 to limit the velocity to 2.5 fps between G-370 and the Northeast pump station. The flow rate of 2350 cfs resulted in a calculated WSEL of 9.9 ft (NAVD) at the Northeast pump station. Per trial and error, a set flow rate of 525 cfs at the Northeast pump station resulted in a total supply flow from Bolles/Cross of 2875 cfs, which resulted in the maximum allowable WSEL of 11.6 ft (NAVD) at the Bolles/Cross intersection. Three pumps are in operation, however, due to the maximum allowable WSEL of 11.6 ft (NAVD) being reached, the pumps would need to be throttled back to 785 cfs each.

Run 2: Setting the WSEL at 8.6 ft (NAVD) and setting the flow rate at G-370 equal to two pumps (2 x 925 cfs) results in a calculated WSEL of 9.4 ft (NAVD) at the Northeast pump station. This lower than Run #1 (9.9 ft (NAVD)) water level, provided a greater differential head and allowed for increased flows in the NNR canal.

Run 3: Setting the WSEL at 8.6 ft (NAVD) and setting the flow rate at G-370 equal to one pump (1 x 925 cfs) resulted in a calculated WSEL of 8.8 ft (NAVD) at the Northeast pump station. This lower than Run #2 water level, resulted in slightly less available cross sectional area and consequently velocities were higher and the allowable maximum flow rate at 2.5 fps was slightly less than Run #2. For example, the Run #2 total flow equaled 3110 cfs and Run #3 total flow equaled 2950 cfs. As illustrated in the results table, when the flow rate capacity of G-370 is reduced the an increase in flow rate capacity can occur at the Northeast pump station.

Table 2 NNR Flowing South with Lateral Flows Due to ¾-inch Rain (All Elevations are in NAVD)

Run #	G-370 PS		Northeast PS		B/C	Bolles/ Cross	Lateral
	Flow (cfs)	WSEL (ft)	Flow (cfs)	WSEL (ft)	Flow (cfs)	WSEL (ft)	Flows (cfs)
1	2350 (VC) (1)	8.6 (S)	1575 (S)(VC)	9.8 (C)	2164 (C) (VC)	11.4 (C)	1761 (S)
2	1850 (S)(2)	8.6 (S)	1961 (S)(VC)	9.4 (C)	2050 (C) (VC)	10.9 (C)	1761 (S)
3	925 (S)(3)	8.6 (S)	2736 (S)(VC)	8.8 (C)	1900 (C) (VC)	10.3 (C)	1761 (S)

(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable
(EC) – Elevation controlled variable (FC) – Freeboard controlled variable.

(1) Existing pump capacity is 925 cfs each, 2,350 cfs flow rate requires throttling 3 pumps to 785 cfs each.
(2) Two 925 cfs pumps.
(3) One 925 cfs pump.

Run 1: Setting the WSEL at 8.6 ft (NAVD) resulted in a calculated maximum allowable flow rate of 2350 cfs at G-370 to limit the velocity to 2.5 fps between G-370 and the Northeast pump station. The flow rate of 2350 cfs (considering the 745 cfs lateral flow shown on Figure 4) resulted in a calculated WSEL of 9.8 ft (NAVD) at the Northeast pump station. Per trial and error, a set flow rate of 1575 cfs at the Northeast pump station resulted in a total supply flow from Bolles/Cross of 2164 cfs (considering the 1016 cfs lateral flow shown on Figure 4), which resulted in the calculated WSEL of 11.4 ft (NAVD) at the Bolles/Cross intersection.

Run 2: Setting the WSEL at 8.6 ft (NAVD) and setting the flow rate at G-370 equal to two pumps (2 x 925 cfs) results in a calculated WSEL of 9.4 ft (NAVD) at the Northeast pump station. This lower than Run #1 water level, provided a greater differential head and allowed for increased flows in the NNR canal. Additionally, because lateral flows introduced along the canal and are not conveyed the entire distance from the Bolles/Cross intersection, the maximum potential flow at the Northeast pump station is approximately 700 cfs greater than the dry season operating condition show in Table 1, Run #2.

Run 3: Setting the WSEL at 8.6 ft (NAVD) and setting the flow rate at G-370 equal to one pump resulted in a calculated WSEL of 8.8 ft (NAVD) at the Northeast pump station. This lower than Run #2 water level, resulted in slightly less available cross sectional area and consequently velocities were higher and the allowable maximum flow at 2.5 fps was slightly less than Run #2. For example, Run #2 total flow equaled 3811 cfs (2050+1761) and Run #3 total flow equaled 3661 cfs (1900+1761).

Table 3 NNR Flowing South with Lateral Flows Due to 1 ½ -inch Rain

(All Elevations are in NAVD)

Run #	G-370 PS Flow (cfs)	G-370 PS WSEL (ft)	Northeast PS Flow (cfs)	Northeast PS WSEL (ft)	B/C Flow (cfs)	Bolles/ Cross WSEL (ft)	Lateral Flows (cfs)
1	2350 (VC) (1)	8.6 (S)	2272 (S)(VC)	9.7 (C)	1100 (C) (VC)	10.8 (C)	3522 (S)
2	1850 (S)(2)	8.6 (S)	2682 (S)(VC)	9.3 (C)	1010 (C) (VC)	10.4 (C)	3522 (S)
3	1490 (S)(3)	8.6 (S)	2971 (S)(VC)	9.0 (C)	940 (C) (VC)	10.1 (C)	3522 (S)

(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable
(EC) – Elevation controlled variable (FC) – Freeboard controlled variable.

(1) Existing pump capacity is 925 cfs each, 2,350 cfs flow rate requires throttling 3 pumps to 785 cfs each.
(2) Two 925 cfs pumps.
(3) Flow equal to lateral inflow. Requires throttling two pumps to 745 cfs each.

Run 1: Setting the WSEL at 8.6 ft (NAVD) resulted in a calculated maximum allowable flow rate of 2350 cfs at G-370 to limit the velocity to 2.5 fps between G-370 and the Northeast pump station. The flow rate of 2350 cfs (considering the 1490 cfs lateral flow which is double that shown on Figure 4) resulted in a calculated WSEL of 9.7 ft (NAVD) at the Northeast pump station. Per trial and error, a set flow rate of 2272 cfs at the Northeast pump station resulted in a total supply flow from Bolles/Cross of 1100 cfs (considering the 2032 cfs lateral flow), which resulted in the calculated WSEL of 10.8 ft (NAVD) at the Bolles/Cross intersection.

Run 2: Setting the WSEL at 8.6 ft (NAVD) and setting the flow rate at G-370 equal to two pumps (2 x 925 cfs) results in a calculated WSEL of 9.3 ft (NAVD) at the Northeast pump station. This lower than Run #1 water level, provided a greater differential head and allowed for increased flows in the NNR canal. Additionally, because lateral flows introduced along the canal and are not conveyed the entire distance from the Bolles/Cross intersection, the maximum potential flow at the Northeast pump station is approximately 1400 cfs greater than the dry season operating condition show in Table 1, Run #2.

Run 3: Setting the WSEL at 8.6 ft (NAVD) and setting the flow rate at G-370 equal to one pump resulted in a calculated WSEL of 9.0 ft (NAVD) at the Northeast pump station. This lower than Run #2 water level, resulted in slightly less available cross sectional area and consequently velocities were higher and the allowable maximum flow at 2.5 fps was slightly less than Run #2. For example, Run #2 total flow equaled 4532 cfs (1010+3522) and Run #3 total flow equaled 4462 cfs (940+3522).

Table 4 NNR Flowing North with no Lateral Flows

(All Elevations are in NAVD)

Run #	G-370 PS Flow (cfs)	G-370 PS WSEL (ft)	Northeast PS Flow (cfs)	Northeast PS WSEL (ft)	A-1 Flow (cfs)	Bolles/ Cross WSEL (ft)	Lateral Flows (cfs)
1	0 (S) (C)	10.9 (C)	1225 (S) (FC)	10.9 (C)	1225 (S)	10.6 (S)	0 (S)
2	0 (S) (C)	11.1 (C)	2510 (S) (FC)	11.1 (C)	2510 (S)	9.6 (S)	0 (S)
3	0 (S) (C)	10.8 (C)	2890 (S) (FC)	10.8 (C)	2890 (S)	8.6 (S)	0 (S)

(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable
(EC) – Elevation controlled variable (FC) – Freeboard controlled variable.

Run 1: Setting the WSEL at 10.6 ft (NAVD) at the Bolles/Cross intersection results in a calculated maximum allowable flow rate of 1225 cfs before encroaching upon the minimum 2 foot freeboard.

Run 2: Lowering the WSEL to 9.6 ft (NAVD) at the Bolles/Cross intersection results in greater flow capacity than Run #1 because the lower downstream water level provides for greater differential head and the lower water level provides for more room before encroaching on the 2 foot freeboard.

Run 3: Lowering the WSEL at the Bolles/Cross intersection to 8.6 ft (NAVD) results in even greater flow capacity. At this elevation, the capacity is limited by the maximum velocity requirements of 2.5 fps, instead of encroaching upon the minimum allowable freeboard.

Table 5 NNR Flowing South without Hump no Lateral Flows

(All Elevations are in NAVD)

Run #	G-370 PS Flow (cfs)	G-370 PS WSEL (ft)	Northeast PS Flow (cfs)	Northeast PS WSEL (ft)	B/C Flow (cfs)	B/C WSEL (ft)	Lateral Flows (cfs)
1	2350 (VC) (1)	8.6 (S)	720 (S) (EC)	9.9 (C)	3070 (C) (EC)	11.6 (C) (EC)	0 (S)
2	2170 (VC)	7.6 (S)	830 (S)(VC)	8.9 (C)	3000 (C)(VC)	10.9 (C)(VC)	0 (S)
3	1985 (VC)	6.6 (S)	800 (S)(VC)	8.0 (C)	2785 (C)(VC)	10.0 (C)(VC)	0 (S)

(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable
(EC) – Elevation controlled variable (FC) – Freeboard controlled variable.
(1) Existing pump capacity is 925 cfs each, 2,350 cfs flow rate requires throttling 3 pumps to 785 cfs each.

Run 1: Run #1 from Table 5 simulates the same condition evaluated under Run #1 from Table 1 with the high point (hump) removed. Comparing the two results, an additional 195 cfs (720 cfs – 525 cfs) can be transferred to the Northeast pump station while maintaining the maximum desirable WSEL of 11.6 ft (NAVD) at the Bolles/Cross intersection. Removing the hump results in approximately 7 percent increase in flow (3070 cfs versus 2875 cfs) at Bolles/Cross for this operating condition.

Run 2: Run #2 from Table 5 simulates the same condition as Run #1 from Table 5, with a lower set water elevation at the G-370 pump station. Comparing the results from Run #1 and Run #2, lowering the water level resulted in slightly less available cross sectional area and consequently velocities were higher and the allowable maximum flow to the G-370 pump station was reduced from 2350 cfs to 2170 cfs. This resulted in a reduced total supply flow of 3,000 cfs.

Run 3: Run #3 from Table 5 simulates the same condition as Run #1 and Run #2 from Table 5, with an even lower set water elevation at the G-370 pump station. Comparing the results, the available capacity was further reduced.

Table 6 NNR Flowing North without Hump no Lateral Flows

(All Elevations are in NAVD)

Run #	G-370 PS Flow (cfs)	G-370 PS WSEL (ft)	Northeast PS Flow (cfs)	Northeast PS WSEL (ft)	A-1 Flow (cfs)	B/C WSEL (ft)	Lateral Flows (cfs)
1	0 (S) (C)	10.9 (C)	1310 (S) (FC)	10.9 (C)	1310 (S)	10.6 (S)	0 (S)
2	0 (S) (C)	11.1 (C)	2700 (S) (FC)	11.1 (C)	2700 (S)	9.6 (S)	0 (S)
3	0 (S) (C)	10.9 (C)	3200 (S) (VC)	10.9 (C)	3200 (S)	8.6 (S)	0 (S)

(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable
(EC) – Elevation controlled variable (FC) – Freeboard controlled variable.

Run 1: Run #1 from Table 6 simulates the same condition evaluated under Run #1 from Table 4 with the high point (hump) removed. Comparing the two results, an additional 85 cfs (1310 cfs – 1225 cfs) can be transferred north from Reservoir A-1 while maintaining the minimum required freeboard of 2 ft. Under this operating condition, removing the hump in the canal yields a 7 percent increase in the capacity.

Run 2: Run #2 from Table 6 simulates the same condition as evaluated under Run #2 from Table 4 with the high point (hump) removed. Comparing the two results, an additional 190 cfs (2700 cfs – 2510 cfs) can be transferred north from Reservoir A-1 while maintaining the minimum required freeboard of 2 ft. Under this operating condition, removing the hump in the canal yields an 8 percent increase in the capacity.

Run 3: Run #3 from Table 6 simulates the same condition as evaluated under Run #3 from Table 4 with the high point (hump) removed. Comparing the two results, an additional 310 cfs (3200 cfs – 2890 cfs) can be transferred north from Reservoir A-1 while maintaining the velocity limit of 2.5 fps. Under this operating condition, removing the hump in the canal yields an 11 percent increase in the capacity.

Table 7 NNR Flowing South without Velocity Restrictions.

(All Elevations are in NAVD)

Run #	G-370 PS Flow (cfs)	G-370 PS WSEL (ft)	Northeast PS Flow (cfs)	Northeast PS WSEL (ft)	B/C Flow (cfs)	B/C WSEL (ft)	Lateral Flows (cfs)
1	1850 (S)	8.6 (S)	1375 (C) (EC)	9.4 (C)	3225 (C) (EC)	11.6 (C) (EC)	0 (S)
2 *	1850 (S)	6.6 (S)	4200 (S) (EC)	7.5 (C)	3150 (C) (EC	11.6 (C) (EC)	2900 (S)
3 *	2775 (S)	8.6 (S)	1900 (S) (EC)	10.0 (C)	1775 (C) (EC	11.6 (C) (EC)	2900 (S)

(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable
(EC) – Elevation controlled variable (FC) – Freeboard controlled variable.

* Simulation assumes no hump and no maximum velocity.

Run 1: Run #1 from Table 7 simulates the same condition evaluated under Run #2 from Table 1 only the velocity limits were not applied. Therefore, instead of velocity limiting the available capacity, the target WSEL of 11.6 ft (NAVD) at the Bolles/Cross canal intersection was the limiting operating criteria. Comparing the two results, an additional 115 cfs (3225 cfs – 3110 cfs) equal to approximately 4 percent can be transferred south.

Run 2: Run #2 from Table 7 simulates the NNR canal flowing south during a wet period similar to the operating conditions summarized in Tables 2 and 3. Run #2 from Table 7 shows that a total capacity of 6050 cfs (1850 cfs + 4200 cfs) can be accomplished if the hump is removed and the velocity limits are not applied. This is estimated to be approximately 25% greater than flow conditions shown in Tables 2 and 3 for similar operating conditions.

Run 3: Run #3 from Table 7 simulates the NNR canal flowing south during a wet period similar to Run #2 from Table 7 except the maximum pumping capacity at the G-370 pump station is simulated. Under this condition, the high flow rate between the Northeast pump station and the G-370 pump station results in high energy losses and consequently the available flow rate to the Northeast pump station is significantly reduced. Therefore, even when removing the hump and not applying the velocity limits to the analysis, the total capacity of 4676 cfs is very similar to the total capacity available under Run #1 Table 3, which included the hump and did not exceed the 2.5 fps velocity limit.

Table 8 Lateral Inflows to NNR

River Station	3/4" Runoff Lateral Inflow (cfs)	1.5" Runoff Lateral Inflow (cfs)
RS 23	309	618
RS 22	71	142
RS 21	130	260
RS 20	30	60
RS 19	145	290
RS 18	164	328
RS 17	167	334
RS 15	580	1160
RS 11	165	330

FIGURES

Figure 1 Reservoir and Canal Location Map

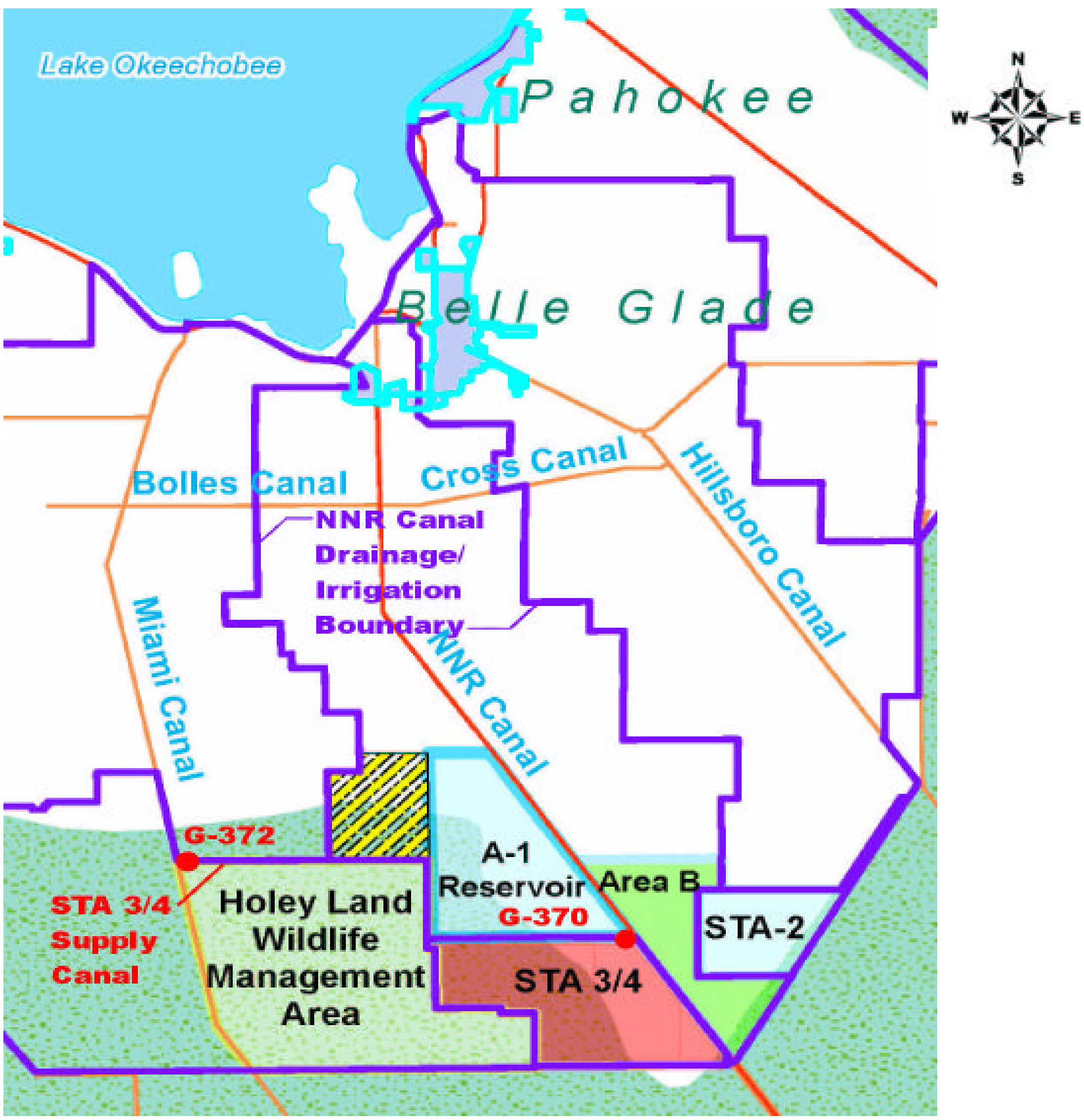
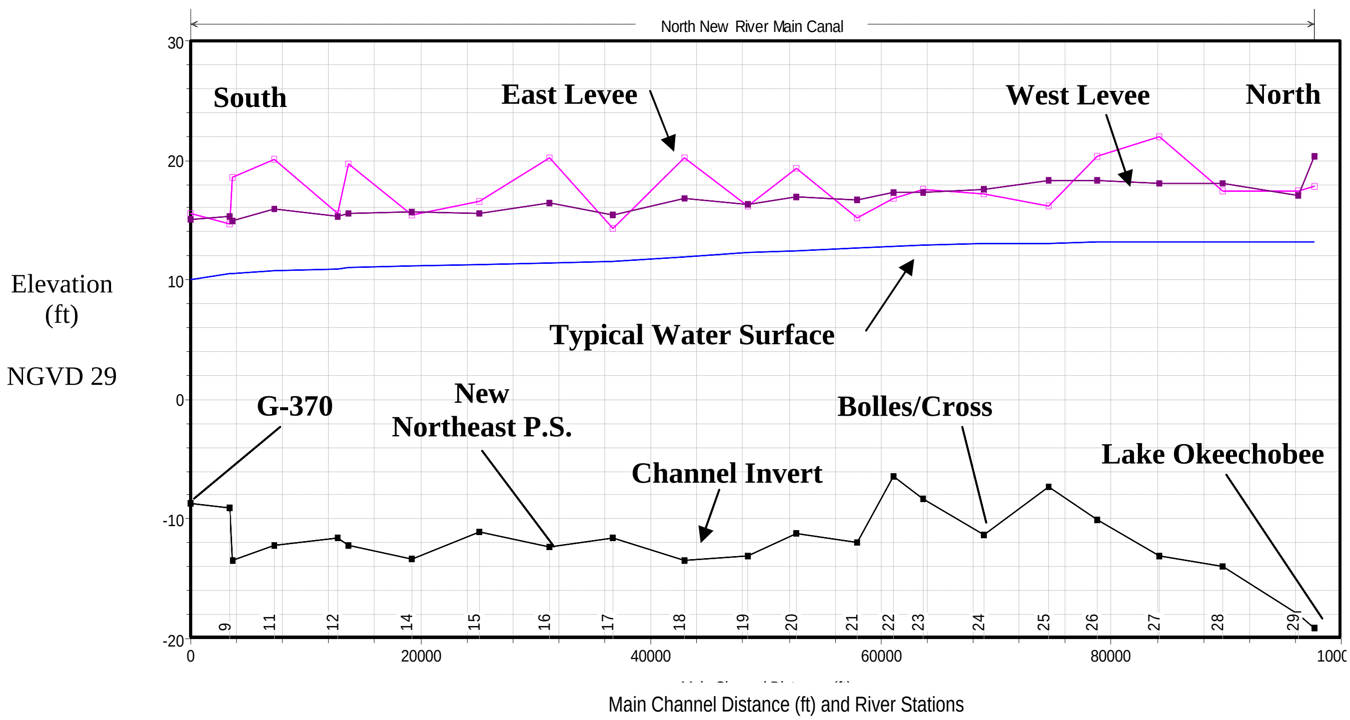


Figure 2 NNR Canal Profile



Elevation (ft) is NGVD 29
NGVD 29 – 1.4 ft. = NAVD88

Figure 3 NNR Flowing South – Dry Conditions

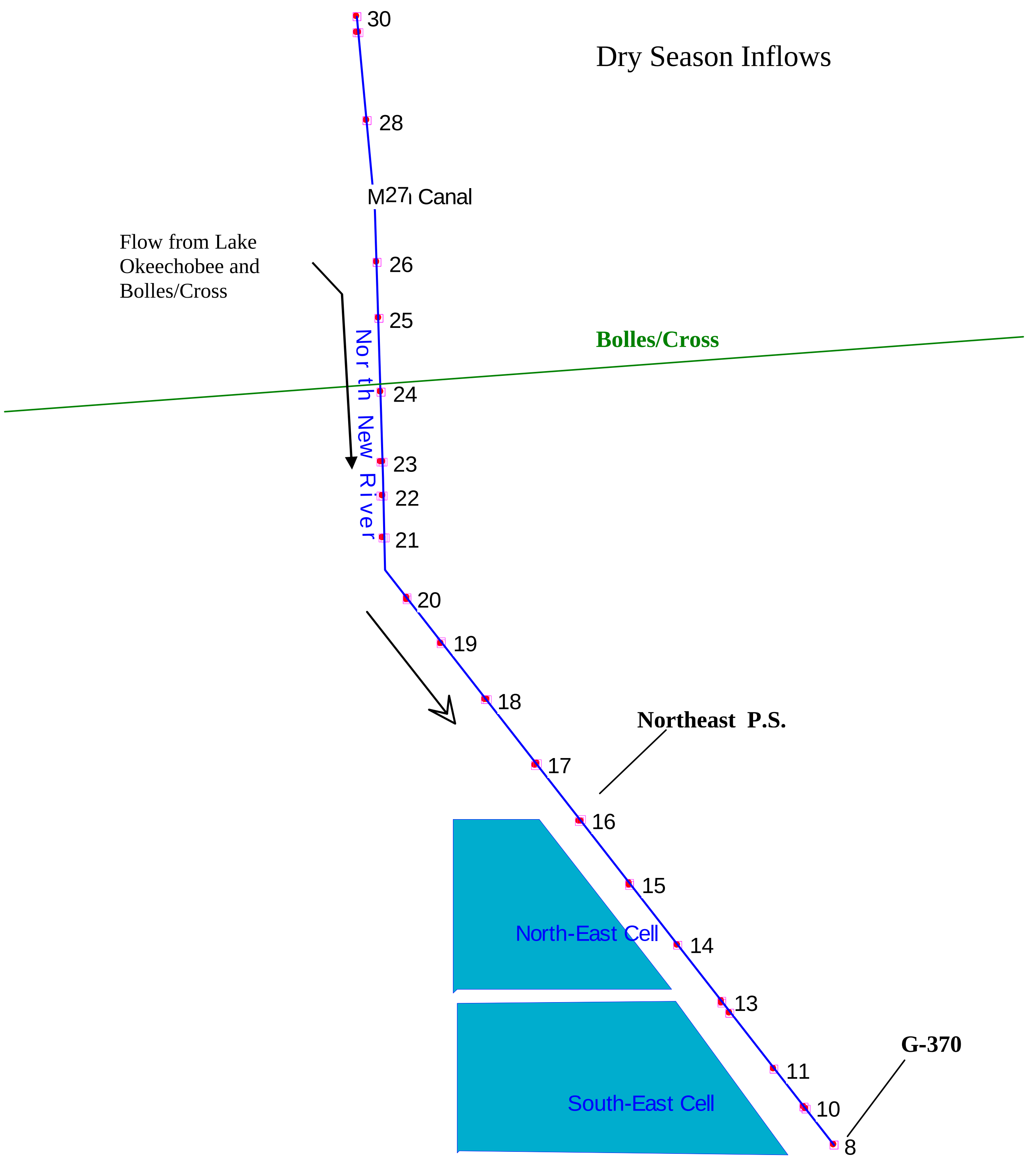


Figure 4 NNR Flowing South – Wet Conditions (3/4-inch Wet Season)

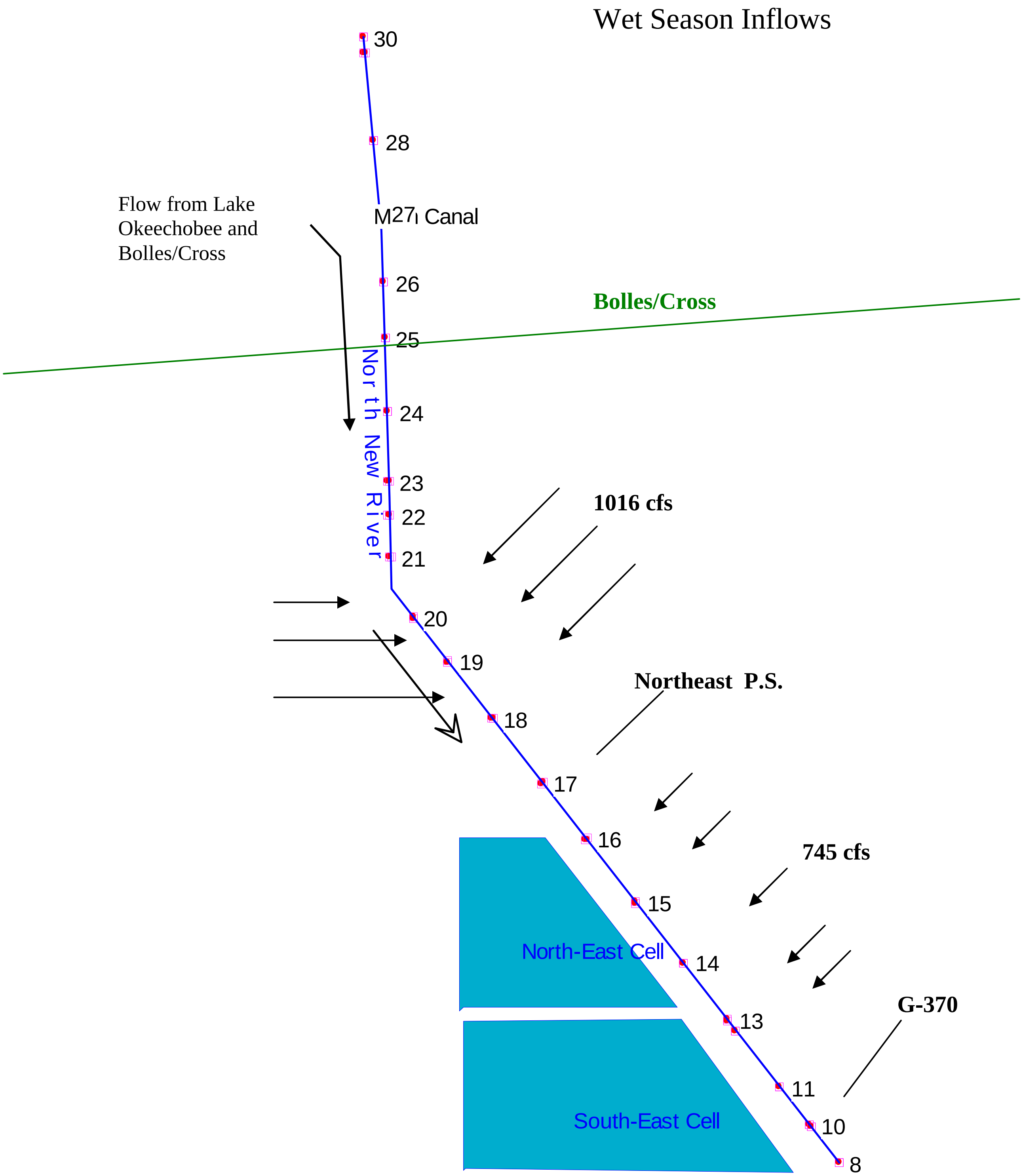


Figure 5 HEC-RAS Model of the EAA System

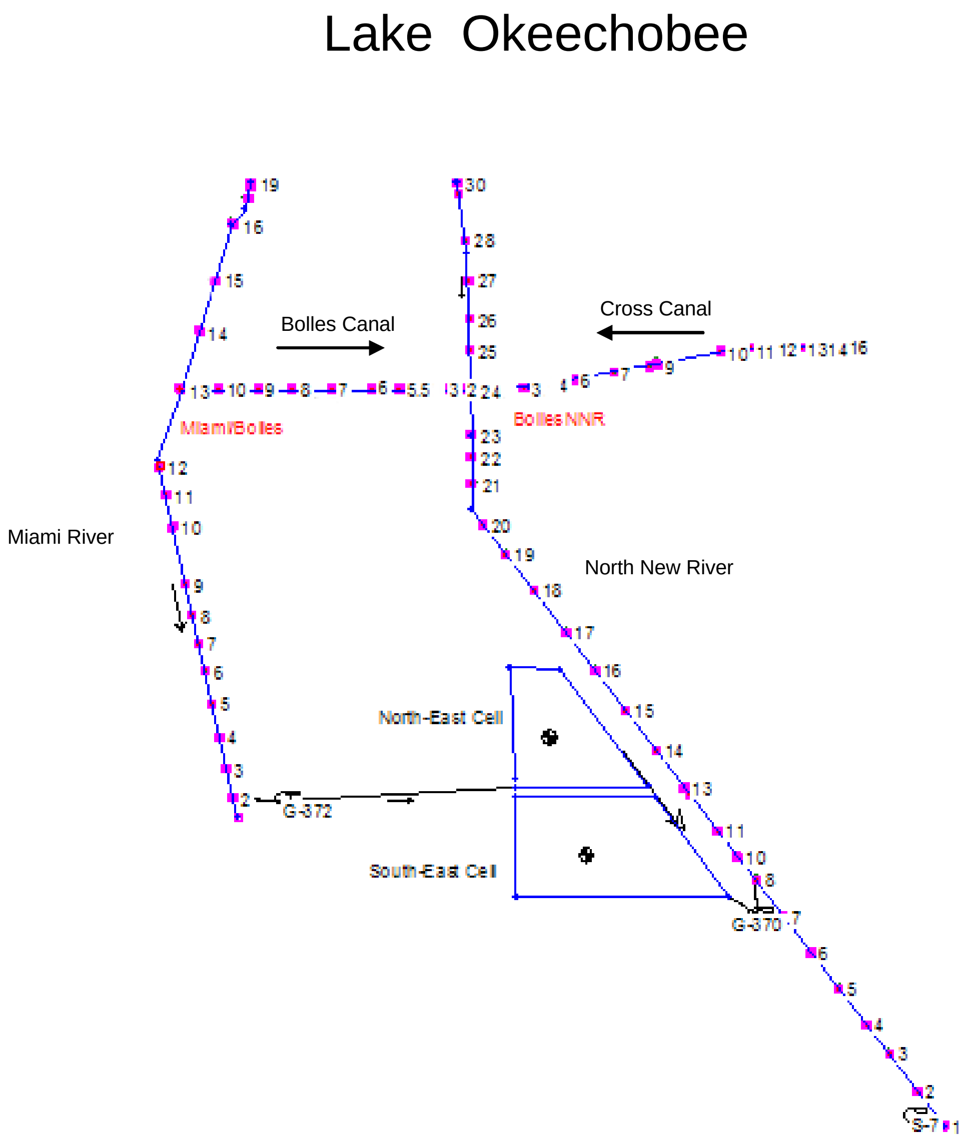


Figure 6 Northeast Pump Station Operating Range

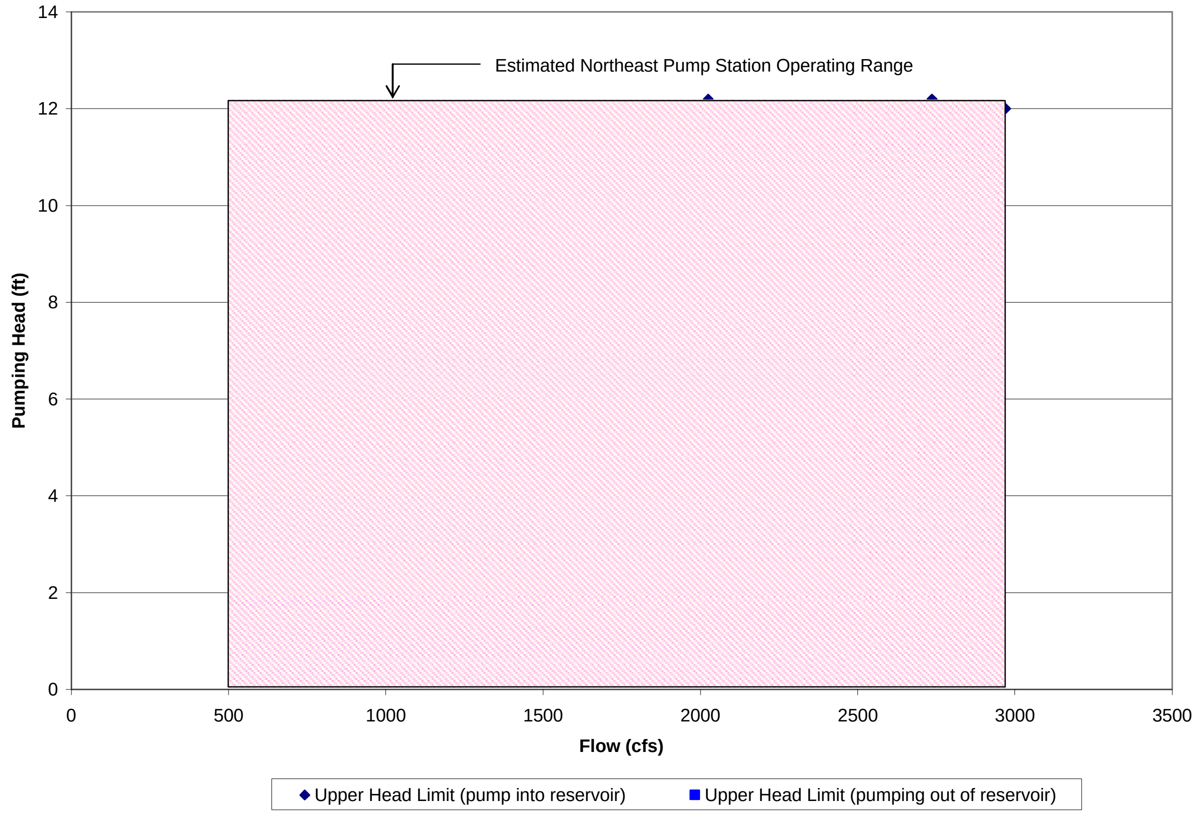
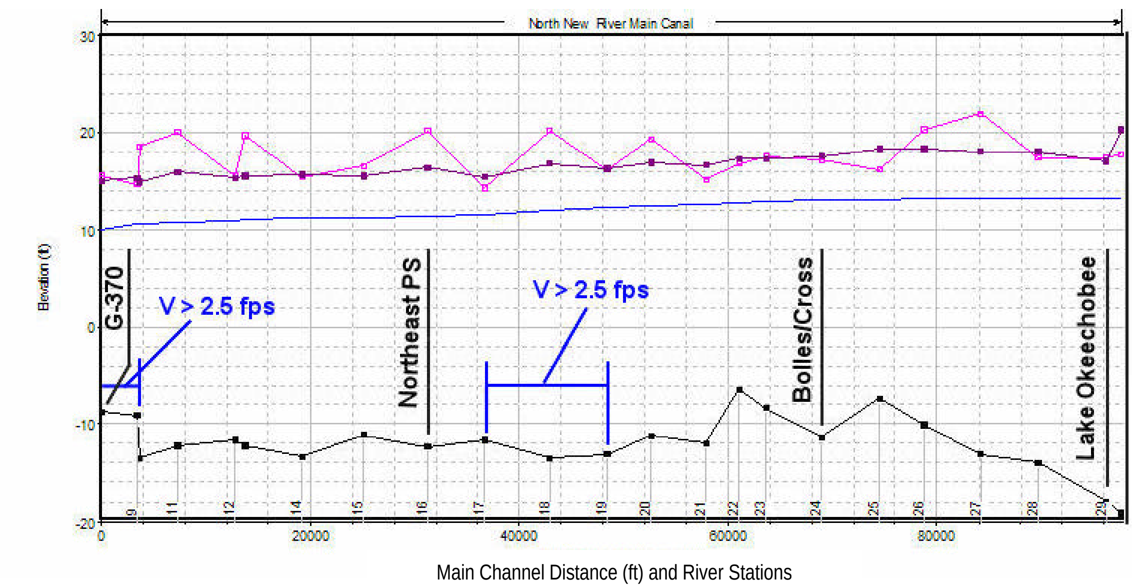


Figure 7 NNR Canal Locations with Constrictions



Elevation (ft) is NGVD 29
NGVD 29 – 1.4 ft. = NAVD88